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SUBJECT: Space Station Configuration and Flight Attitude - Case 620

DATE: August 1, 1969

FROM: G. M. Anderson

ABSTRACT

The influence of pointing and rotational requirements on the design of a space station is examined. The design objective is to provide complete pointing and rotational flexibility with only rigid body module rotations and experiment gimbals.

A solution is presented for an idealized case. The configuration has cylindrical geometry with modules aligned on one axis. Experiments and the solar array have single gimbals. Targets are accessed by a combination of module and gimbal rotations. The loss in flexibility arising from a modification which relaxes the idealization is also given.

For both cases, the preferred flight attitude is with the symmetry axis aligned with the perpendicular to the orbital plane.

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MEMORANDUM FOR FILE

I. INTRODUCTION

This memorandum examines the influence of pointing and rotational requirements on space station configuration and flight attitude design. The design objective is to provide the capability for meeting all of these requirements simultaneously and without mutual compromise.*

One way of solving the problem of conflicting pointing requirements is to provide a free flight capability. Systems with common pointing requirements are placed on a common module which is separated from the space station for operational use and periodically returned for service. The required pointing flexibility is obtained in this method at a high cost. The separated module must provide all the usual spacecraft functions. Orbit keeping, rendezvous, and docking impose additional burdens on the overall system.

Logically, the separated module concept may be over-killing the problem. It provides six degrees of rigid body freedom for each module, where only two at most may be required. With two orthogonal rotations a vector representing a pointing direction may be repositioned to any desired direction.

It seems useful to inquire whether it is possible to configure a space station from modules with only rotational freedom. While two rotations are necessary for full pointing flexibility, they do not insure that the desired target can actually be seen. The target may be obscured by the space station itself.

The configuration design problem comes down to finding a geometry with adequate rotational flexibility which avoids the problem of target obscuration.

An answer is given here in two parts. First, an idealized concept is presented which ignores certain practical considerations. For this idealization it is asserted that:

* The configurations derived here are anticipated in part in Reference 1.

(a) There is an optimum geometry with the modules assembled along one axis, designated the symmetry axis. Module rotations are about this axis and experiments are gimbaled about an orthogonal axis.

(b) For this configuration, and subject to the assumptions, all the space station pointing and rotational requirements can be met simultaneously.

Second, using this concept as a guide, the configuration is modified to relieve the limitations of the assumptions. This results in some loss in capability. Whether or not the remaining flexibility is adequate in any given case can only be assessed in terms of actual requirements. No general answer can be given in advance.

The preferred flight attitude for the configurations discussed is with the symmetry axis perpendicular to the orbital plane.

II. POINTING REQUIREMENTS

It is convenient to divide these requirements into three categories, earth, inertial and non-inertial pointing.

Earth Pointing

The space station should have the capability of pointing its earth sensing instruments to any portion of the earth or its atmosphere which is in view at any instant. For a low earth orbit of about 200 n. miles, this requires pointing anywhere within a cone of approximately 90° half angle centered on the nadir.

Earth pointing is a special case of non-inertial pointing which merits separate categorization. Earth pointing will dominate other non-inertial pointing to a large degree. Also, the nadir may be kept in view by a single axis rotation about the perpendicular to the orbital plane. Other non-inertial targets usually will not have this property.

Inertial Pointing

Requirements to point instruments at arbitrary targets on the celestial sphere as well as at the sun are likely.

In addition, if solar array power is employed, the solar arrays must face the sun continually for efficient use.

Non-Inertial Pointing

Any moving targets which must be acquired and tracked fall into this category. Other low altitude satellites are the source of this requirement.

III. ROTATIONAL REQUIREMENT (Artificial Gravity)

The only practical method currently known to provide a body force simulating that of gravity for long duration is continuous rotation. If an artificial gravity requirement is placed on the space station, provision must be made for a rotating module. There is freedom on the choice of the axis of rotation.

IV. MODULES AND GIMBALS

As implied earlier, the space station in the sense developed here is an assembly of modules which can rotate but not translate with respect to each other. All systems with common pointing requirements are placed on a common module.

Experiment pointing may be achieved by

a) module rotations about two axes,

b) one module rotation and one gimbal rotation, or

c) two gimbal rotations.

It is important to observe that (a) and (b) provide complete flexibility to point in any direction. Option (c) however, in general can access only one-half the celestial sphere since the module on which the experiment is mounted obscures the view of the remainder. For this reason, option (c) is eliminated from the idealized case.

V. ASSUMPTIONS FOR IDEALIZED CASE

The following assumptions are used:

a) Dimensions of pointing instruments are small compared to the diameter of the module which carries them. Instruments are on the surface of the module.

b) Module size is not constrained.

c) Space station size is not constrained.

d) Crew transfer between modules shall not require extra-vehicular activity (EVA) nor the inclusion of non-rigid body (bellows) elements.

VI. IDEALIZED CONCEPT

The configuration problem is to assemble the following modules so as to avoid target obscuration and provide full pointing and rotational flexibility:

a) Modules carrying instruments, mounted with or without gimbals.

b) Rotational module for artificial gravity.

c) Solar array for electrical power.

One answer to this problem consistent with the assumptions has the following properties:

All modules have the same diameter and are aligned on a common axis, the symmetry axis.

Only single axis module rotations about the symmetry axis are allowed.

Gimbal pointing of experiments on an axis orthogonal to the symmetry axis is required for the second degree of freedom.

The concept is illustrated in Figure 1. Of the two remaining alternatives, a and b of Section IV, for experiment pointing, alternative b has been selected. Alternative a uses two module rotations which appears to make much more complex the problem of crew transfer between modules. Additionally two module rotations make continuous target visibility more difficult, if not impossible, to manage.

Alternative b, of Section IV, requires only one rotational degree of freedom between adjacent modules. Crew transfer can be accomplished by means of a transfer airlock which can assume the rotation rate of either of the adjacent modules.

Aligning all modules on a common rotational axis has two attributes. First, in conjunction with the requirement that all modules have the same diameter, it provides a solution for the target obscuration problem. Second, it decouples modules from the effects of rotation of other elements in the configuration.

Notice that the solar array must be made as a venetian blind. For a large tilt angle normal to the symmetry axis, it must be located a large distance from the adjacent modules.

Since the experiments are mounted on the surface of the modules they can be arbitrarily pointed through a combination of module and gimbal rotations.

VIII. MODIFIED CONCEPT

Figure 2 illustrates a conceptual design which relaxes some of the assumptions of Section V.

The maximum diameter is set here by the solar array or the artificial gravity module. This diameter is not permitted to control the diameter of the other modules which results in some loss of viewing. For earth pointing the solar array will obscure part of the earth but only for a fraction of the orbit and never along the nadir. The artificial gravity module since it is not a solid cylinder, obscures targets only intermittently which may be tolerable.

Since the astronomy module may contain experiments which are of comparable size to the space station diameter, it may be necessary to mount them on the end of the configuration. This restricts viewing to one-half the celestial sphere at any one time. Periodically the entire configuration could be flipped 180 degrees to permit access to the other half.

VII. FLIGHT ATTITUDE

The POP attitude is ideal for the configuration discussed here for two reasons:

a) It is easy to stablize with control moment gyros (CMG's) and

b) Earth pointing along the nadir is accomplished with only module rotation.

G. M. Anderson

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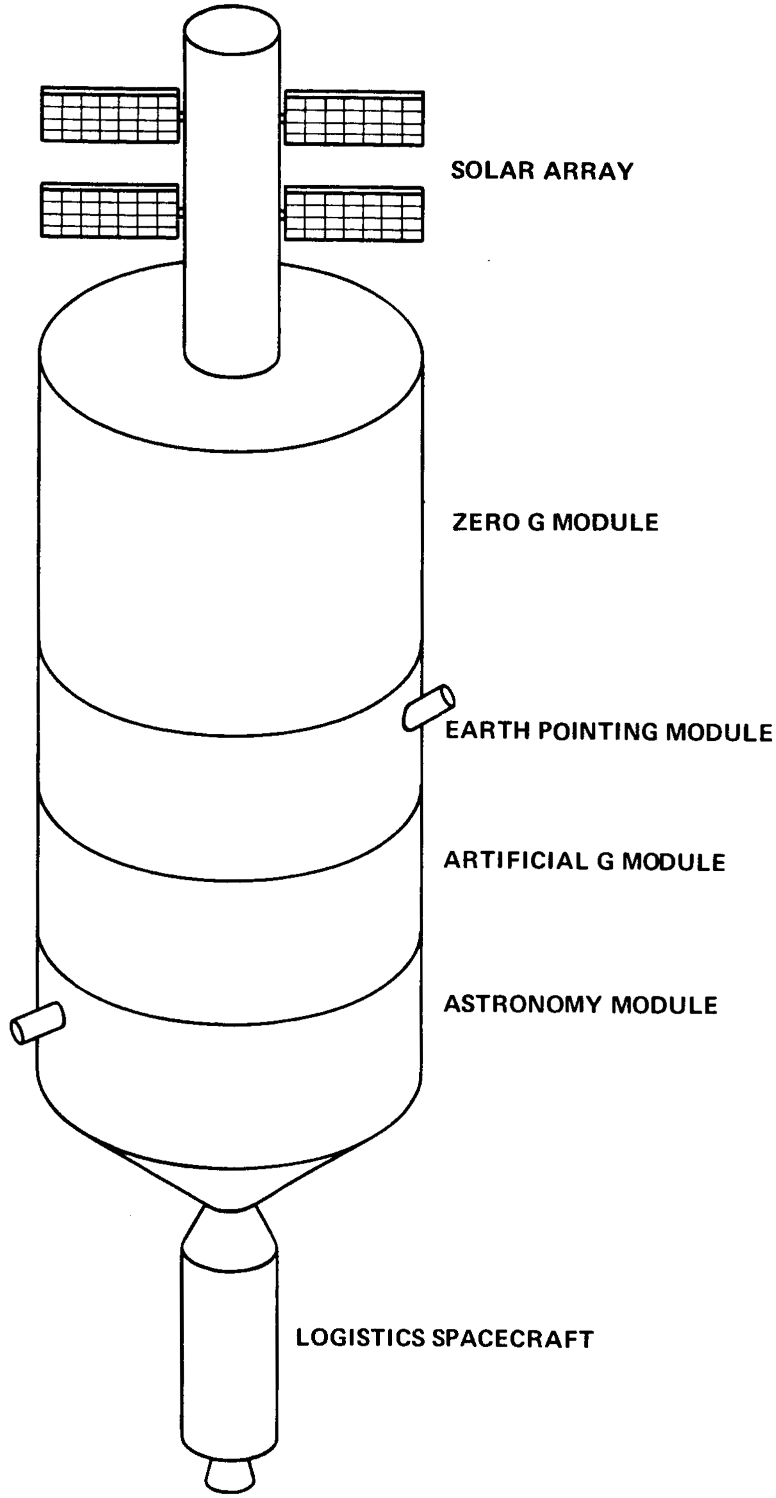

FIGURE 1 - IDEALIZED CONCEPT

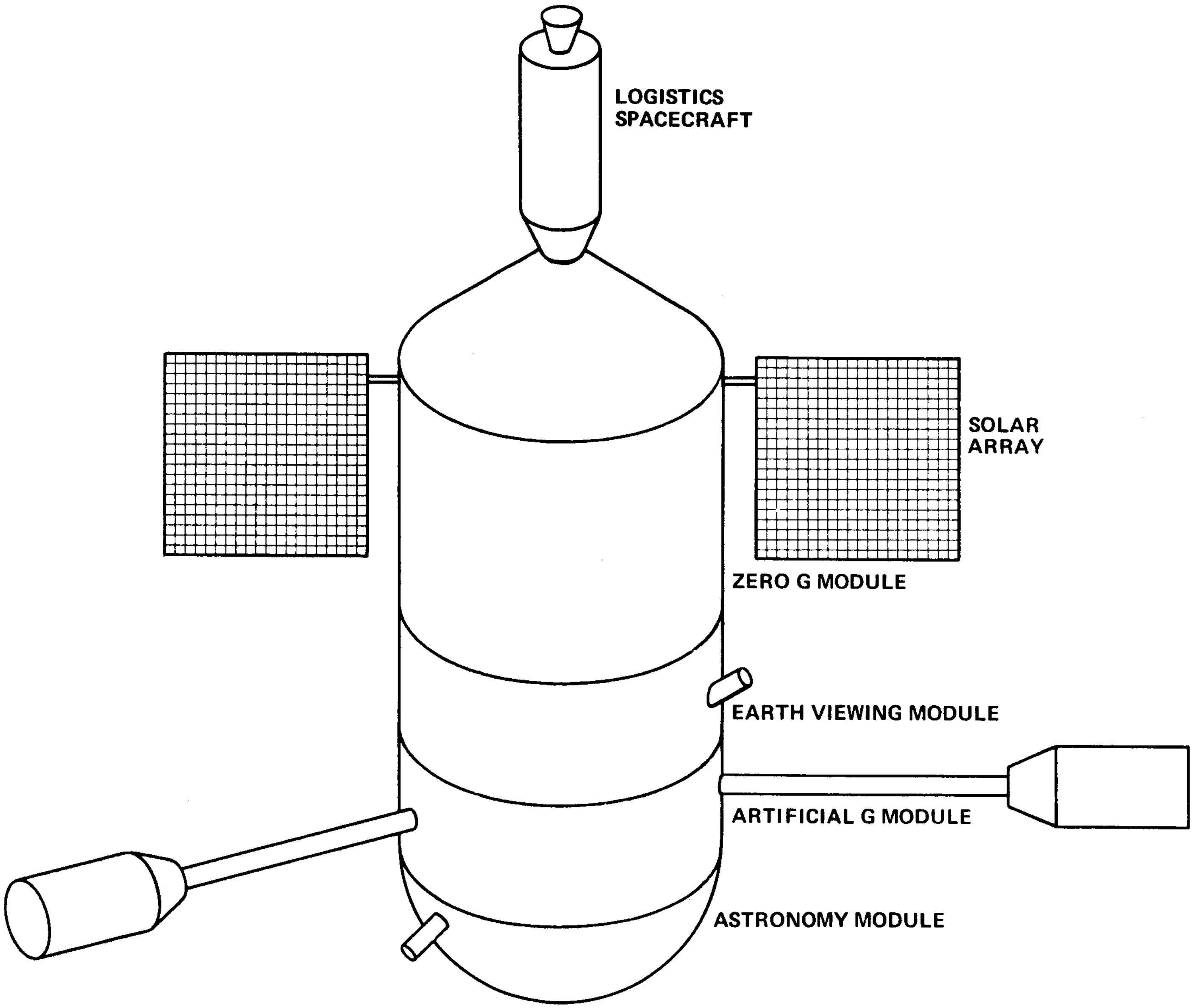

FIGURE 2 - MODIFIED CONCEPT

REFERENCES

1. Statement of Work, Space Station Program Definition, NASA, April 14, 1969.

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